Wind Turbine Generator Failure Modes

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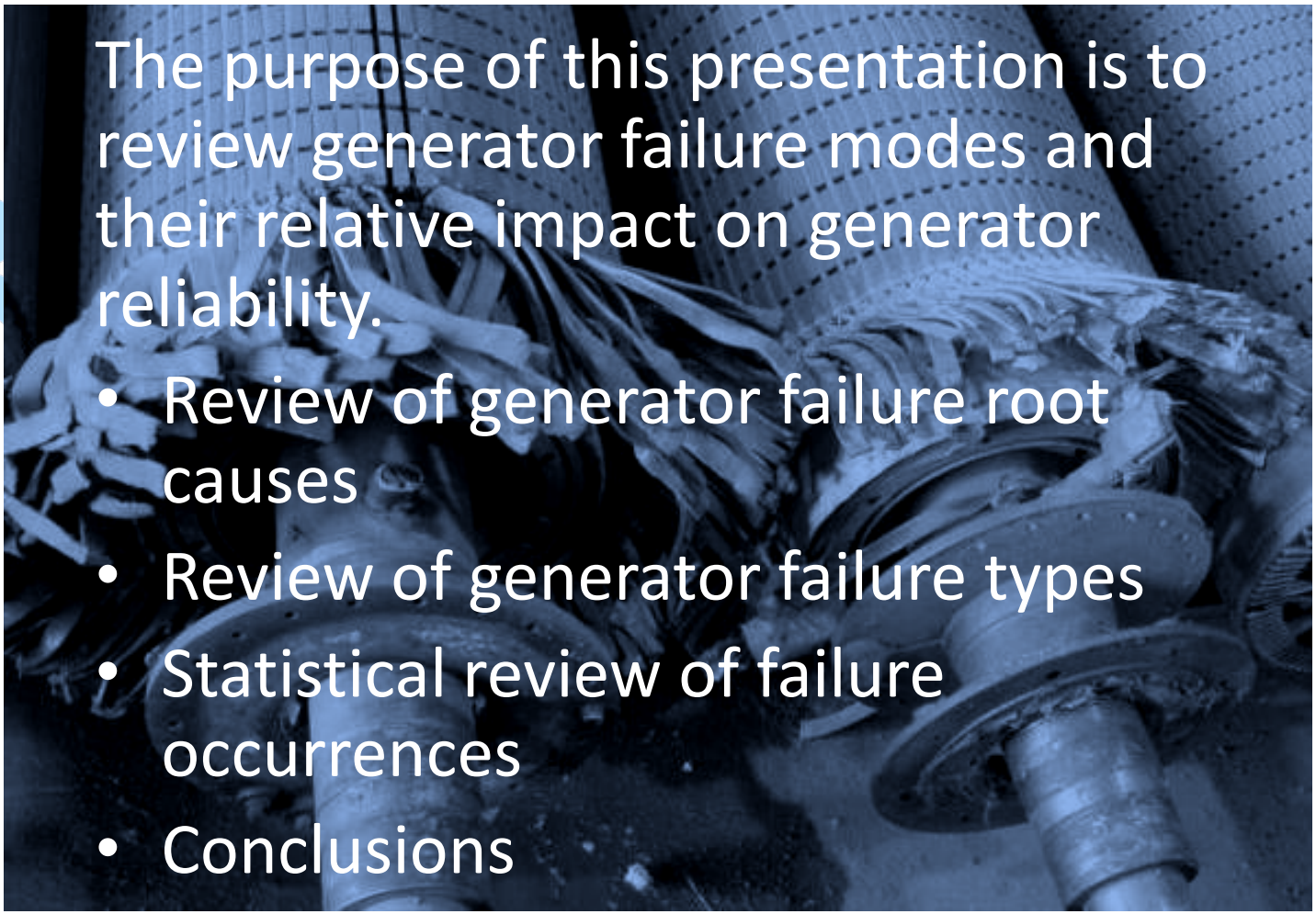
Introduction and Credits



The purpose of this presentation is to review generator failure modes and their relative impact on generator reliability.

- Review of generator failure root causes
- Review of generator failure types
- Statistical review of failure occurrences
- Conclusions

Introduction and Credits

- **Thanks to:**
  - Shermco Industries Technical Staff
  - William Chen, TECO-Westinghouse Motor Company
  - Applications Engineering – Von Roll USA
  - Benoit White, Mersen USA
  - P.J. Tavner, PhD., University of Durham
- **References:**
  - Root Cause Failure Analysis, Electrical Apparatus Service Association, 2002-2004
  - Design Challenges of Wind Turbine Generators , George Gao and William Chen – IEEE EIC 2009
  - A Survey of Faults on Induction Motors… , O.V. Thorsen and M. Dalva - IEEE Trans. on Industrial Applications – 1995
  - Wind Turbine Failure Modes Analysis and Occurrence, Kevin Alewine and William Chen, AWEA Windpower 2010
  - Establishing an In-House Wind Maintenance Program, American Public Power Association, 2008

Generator Failure Root Causes

- Design issues – materials and processing, rarely basic mechanical design
- Operations issues - alignment, vibration, voltage irregularities, improper grounding, over-speed, transit damage, etc.
- Maintenance practices – collector systems, lubrication procedures, etc.
- Environmental conditions – weather extremes, lightning strikes, etc.

Design and Manufacturing Issues

- Electrical insulation inadequate for application – normally mechanical rather than electrical weakness
- Loose components – wedges, banding
- Poorly designed/crimped lead connections
- Inadequate collector ring/brush performance
- Transient shaft voltages
- Rotor lead failures
- Sometimes turbine OEMs add components that might complicate service – electronics, lubrication devices, etc.

Operations Issues

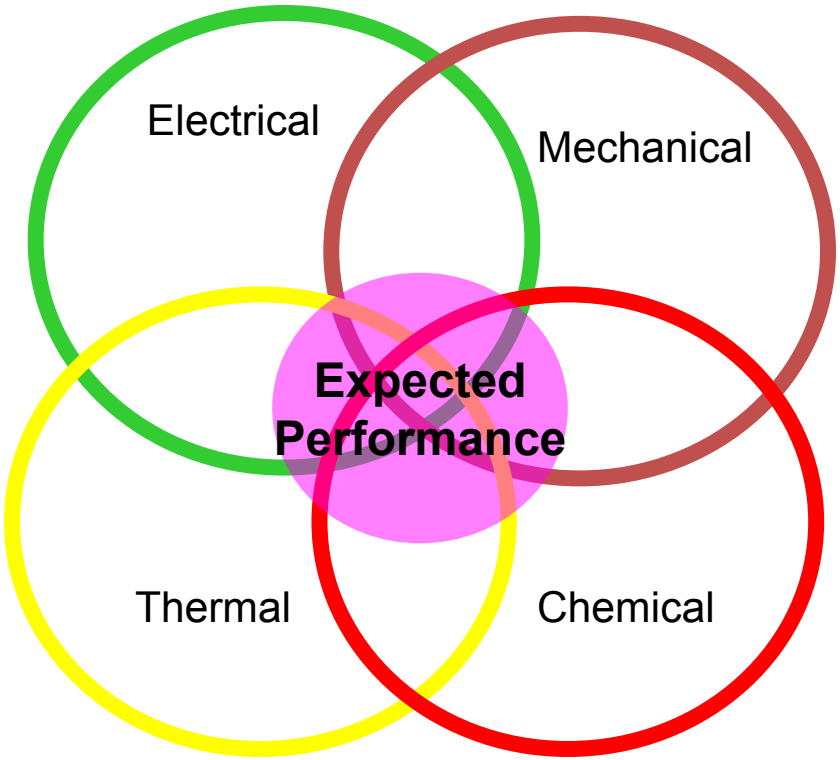
- Improper Installation
- Voltage irregularities
  - Traditional sources
  - Convertor failure or miss-match
- Improper grounding
- Over-speed conditions
- Transit damage

Maintenance Practices

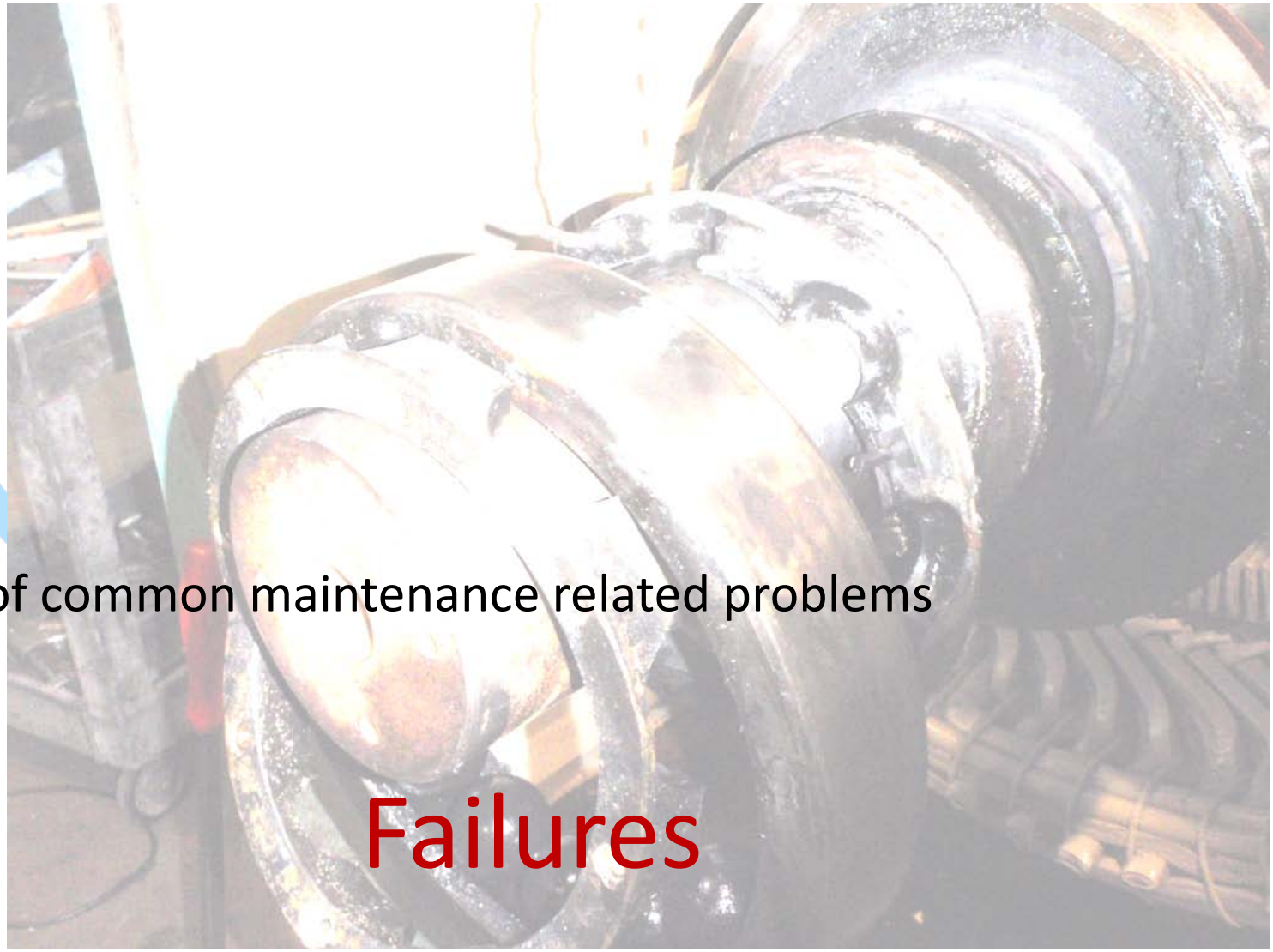
- Ignoring alignment check suggestions
- Cooling system failures leading to heat related failures
- Collector ring contamination
- Bearing mechanical failure
- Bearing electrical failure
- Rotor lead failures
    - Often initiated by heat from failing bearing

Environmental Conditions

- Wind Loading
- Thermal cycling
- Moisture/Arid
- Contamination
- Electrical Storms



A review of common maintenance related problems



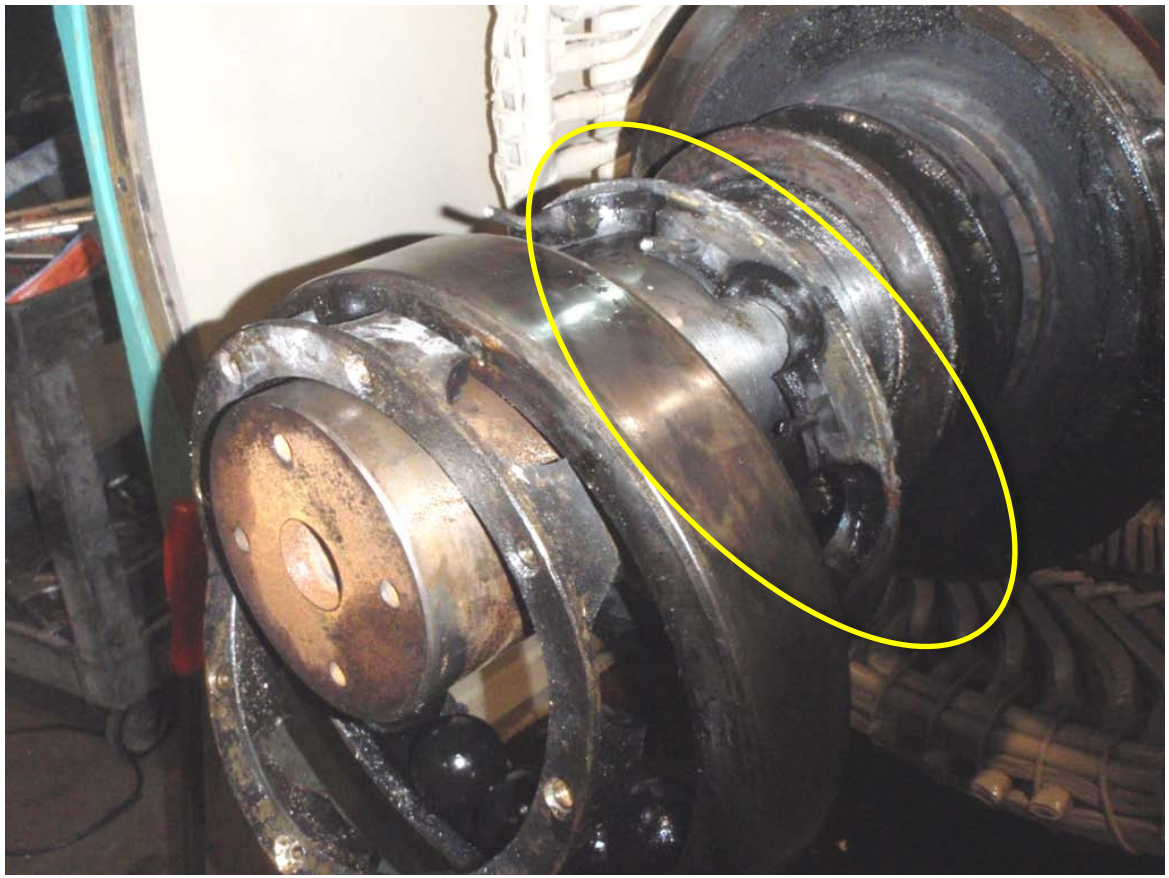
Failures

Anatomy of a Bearing Failure #1

- Over greasing?
- Leaking from fittings?
- Leaking before or after failure?
- Evidence of heat on bearing housing…shaft damage?

Anatomy of a Bearing Failure #1

- Destroyed races
- Bearing collapsed in housing
- Lost ball bearings



Anatomy of a Bearing Failure #1

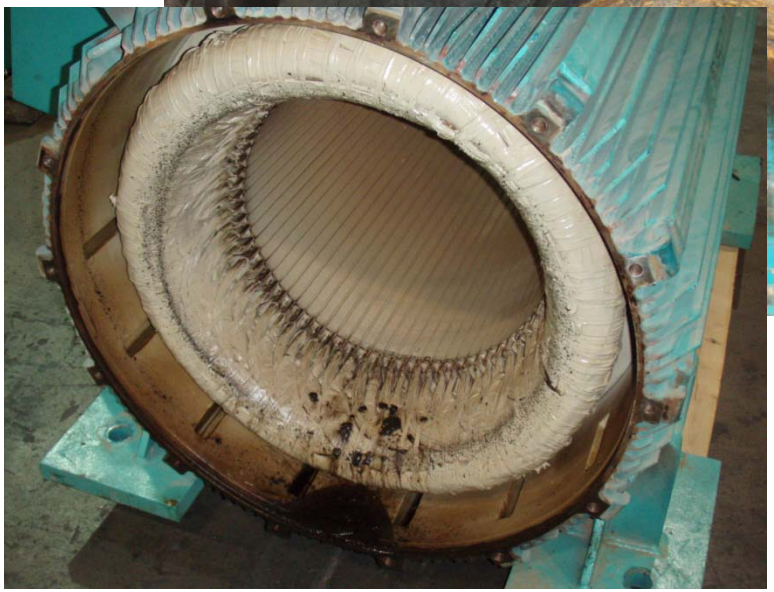
- Heavily scored and damaged shaft
- If damaged on non-drive end, this could include a distorted shaft and burnt rotor leads (DFIG)

Anatomy of a Bearing Failure #2

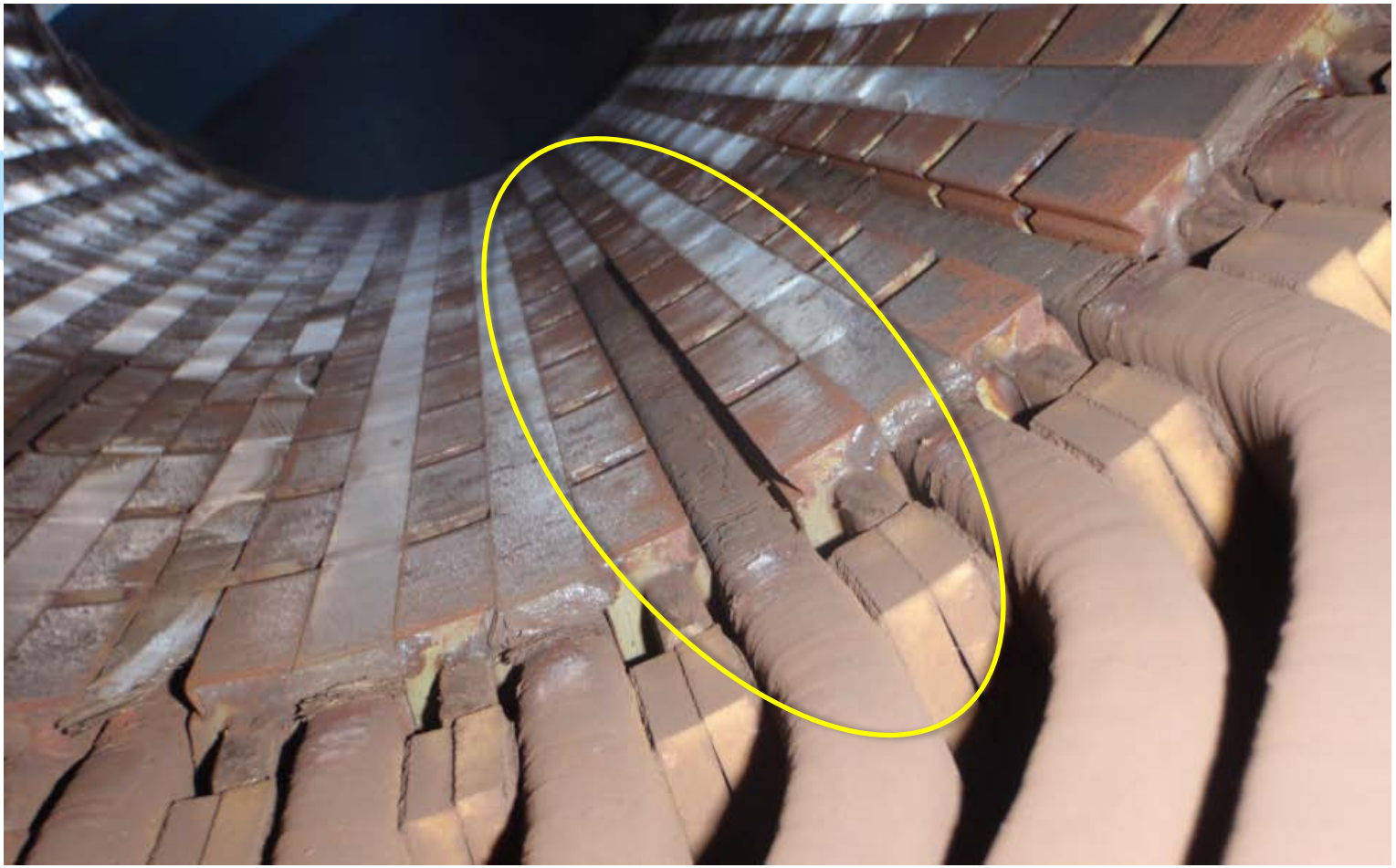
- Overfilled bearing
- Leaking on the exterior into cooling unit, clogging air passages

Anatomy of a Bearing Failure #3

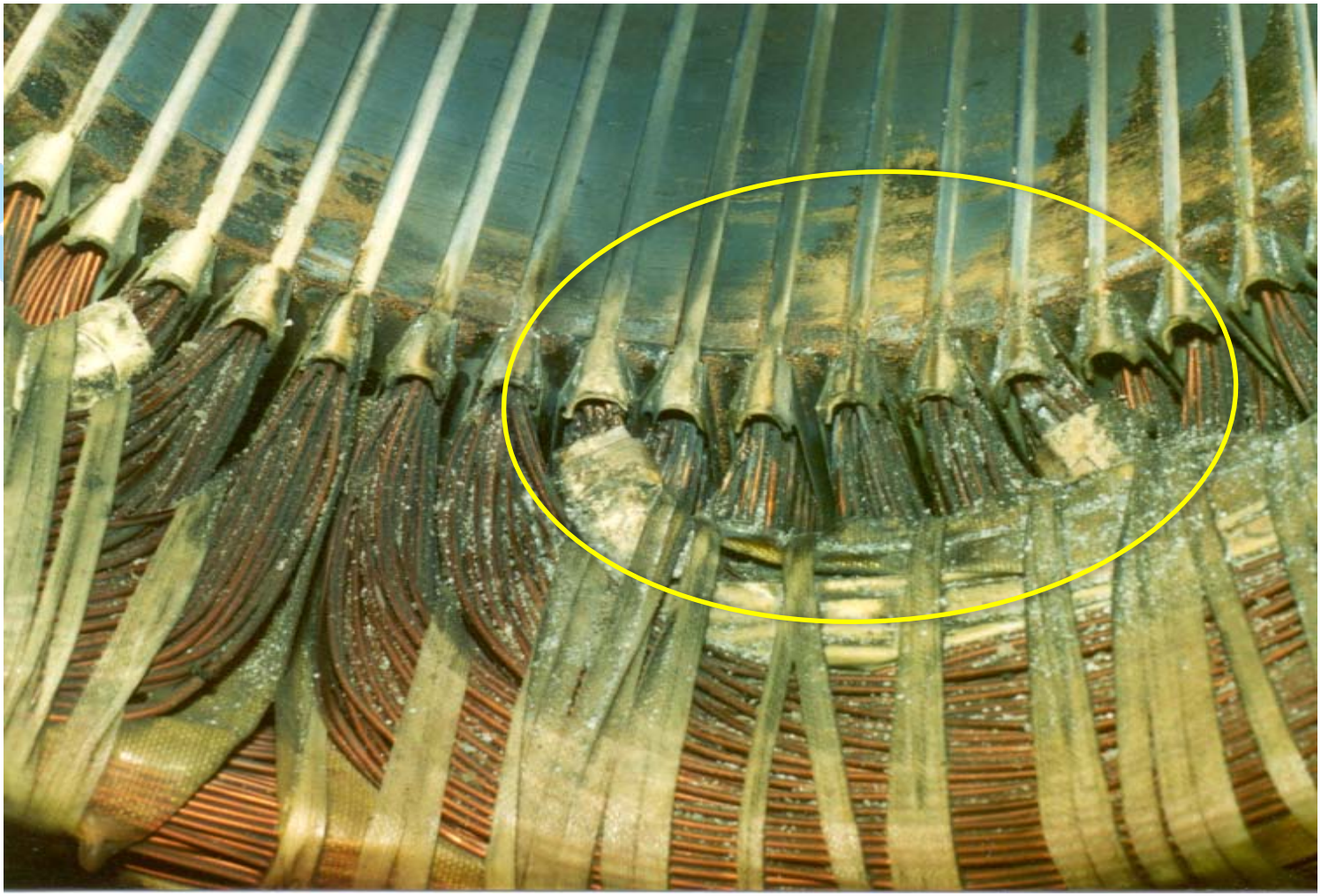
- Overfilled bearing
- Overheated lubrication
- Blocked fill/exit ducts
- Leaking exterior and interior



Magnetic Wedge Loss



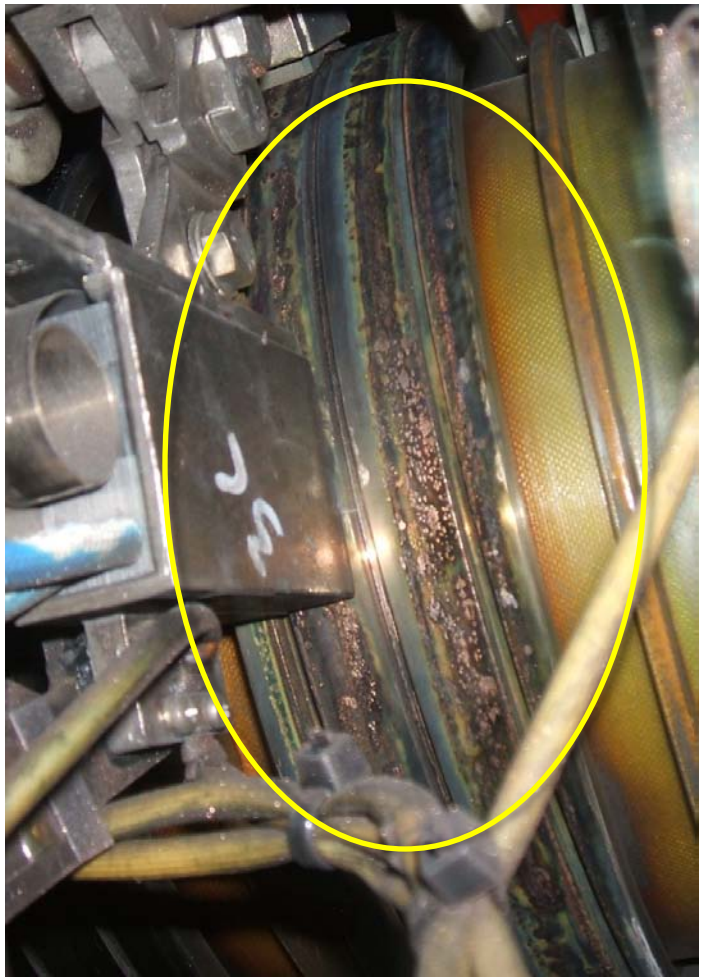
Contamination



Collector Ring and/or Carbon Brush Failures

Possible failure points

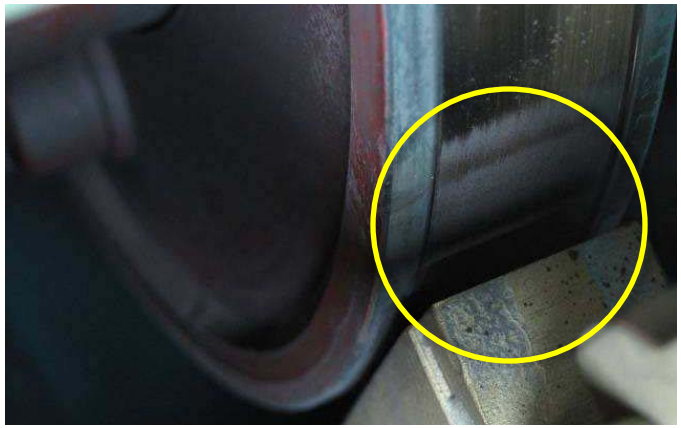
- Short brush life
  - Improper grade
  - Improper seating
  - Improper ring material
  - Environmental issues
- Flash over/grounding
  - Lack of phase isolation
  - High brush wear
  - Improper cleaning during maintenance
- Lead failures
  - Improper design
  - High temperature

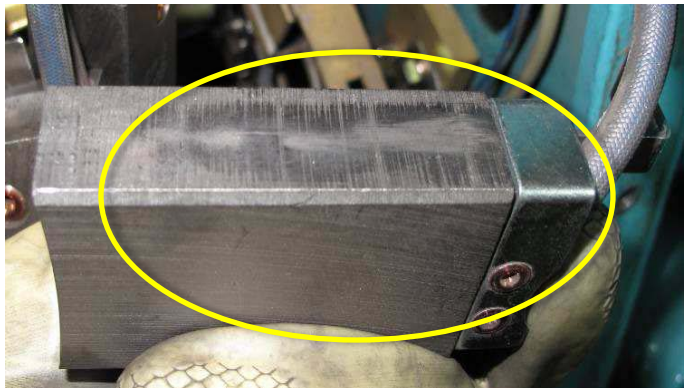


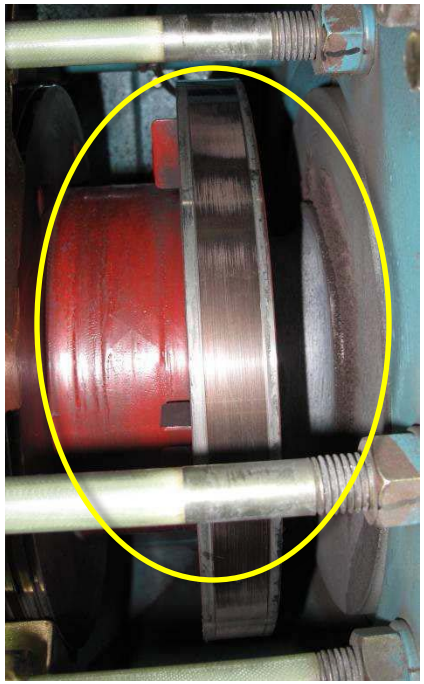
Collector Ring and/or Carbon Brush Failures

Out of round grounding ring

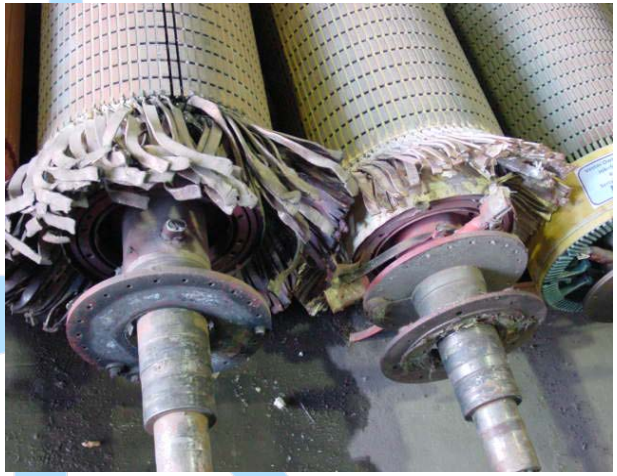
- Brush bounce and chatter
- Premature wear
- Less effective – could still severely damage bearings







Other Failure Modes

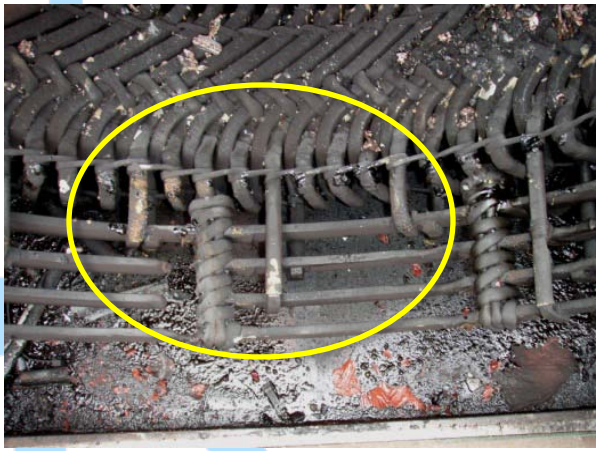


Banding Failure

Rotor lead damage

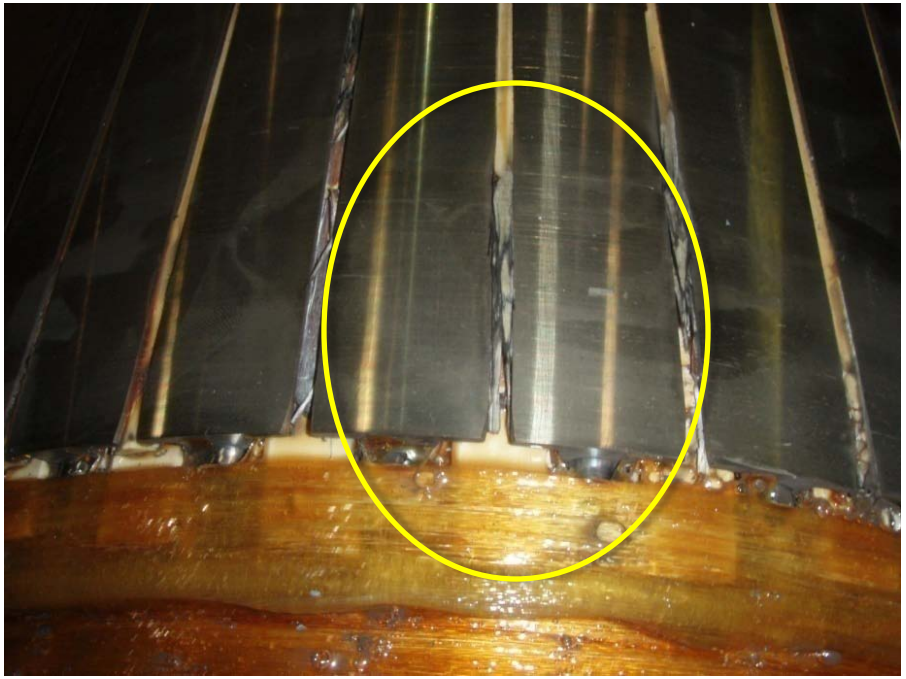
Over-speed Conditions

Other Failure Modes

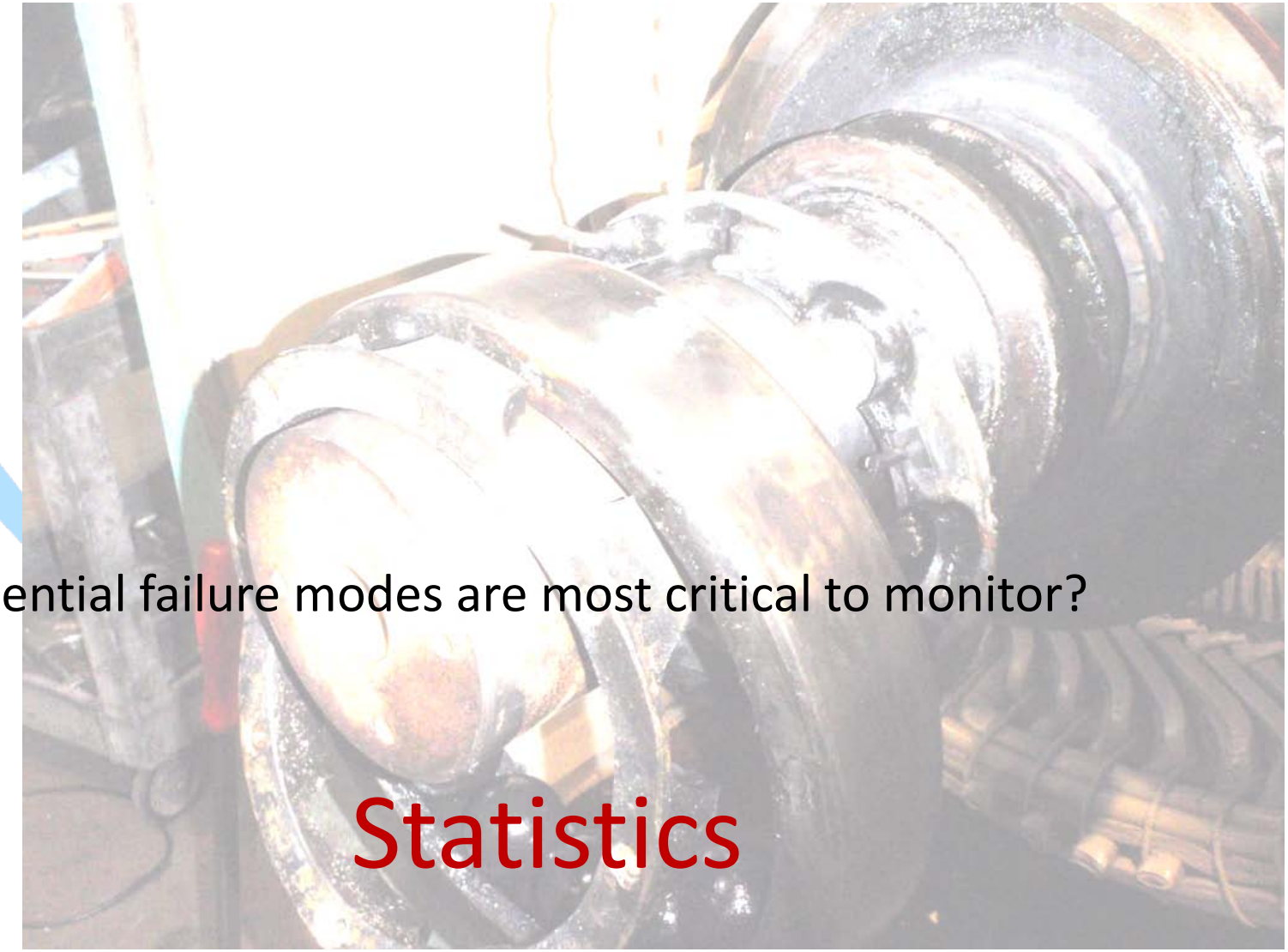


Stator Connection Shorts

Short in Slot Section



Lost Rotor Wedges



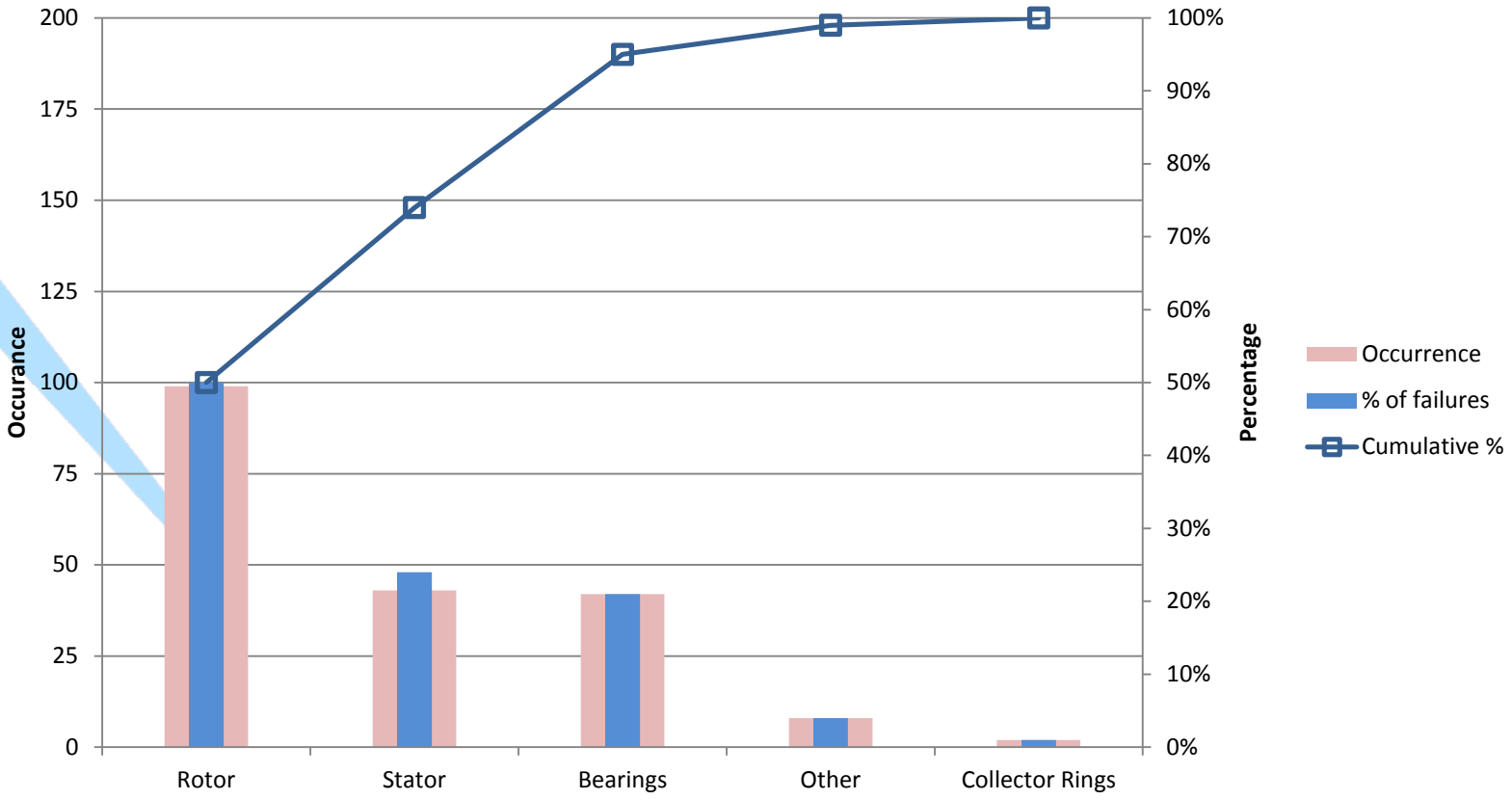
What potential failure modes are most critical to monitor?

Statistics

Occurrences of Failures

- The following statistics were collected from failure reports of over 1200 repair operations performed by Shermco Industries between 2005 and 2010, totaling nearly 2 gigawatts
- 3 generator categories based on nameplate output power
  - Small (<1MW)
  - Medium (1-2MW)
  - Large (>2MW)

Generators <1MW



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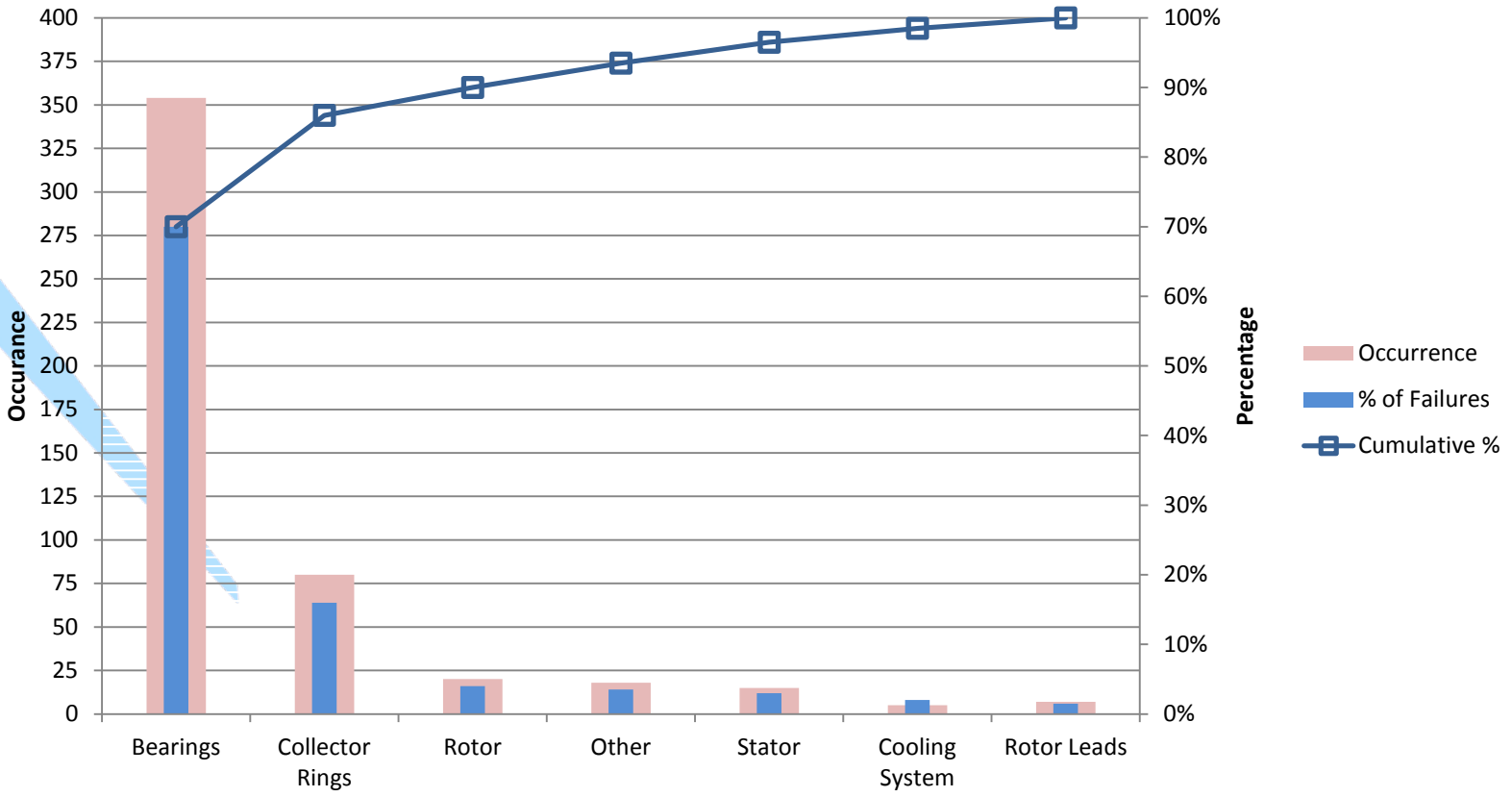
Generators 1-2MW



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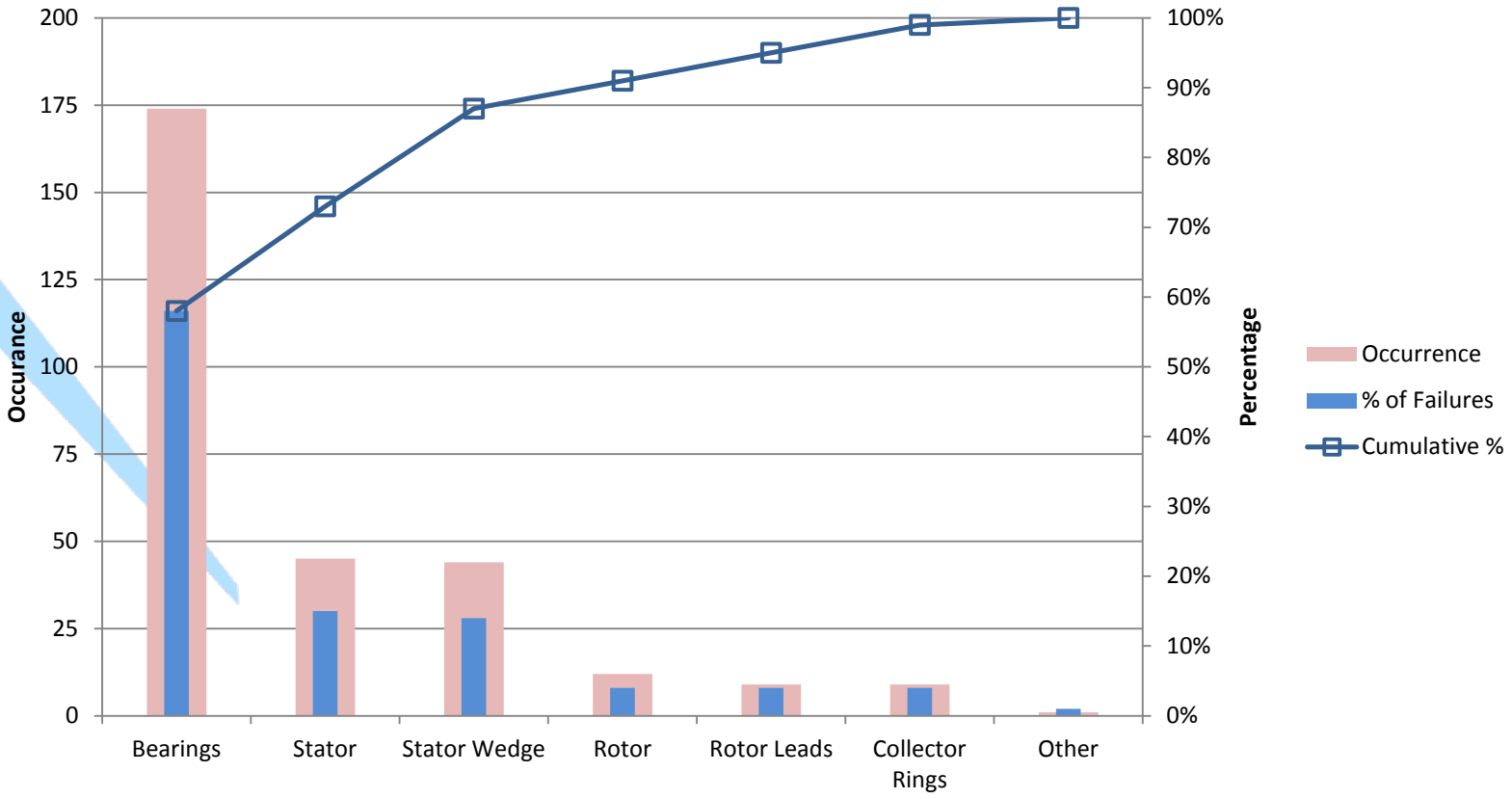
Generators > 2MW



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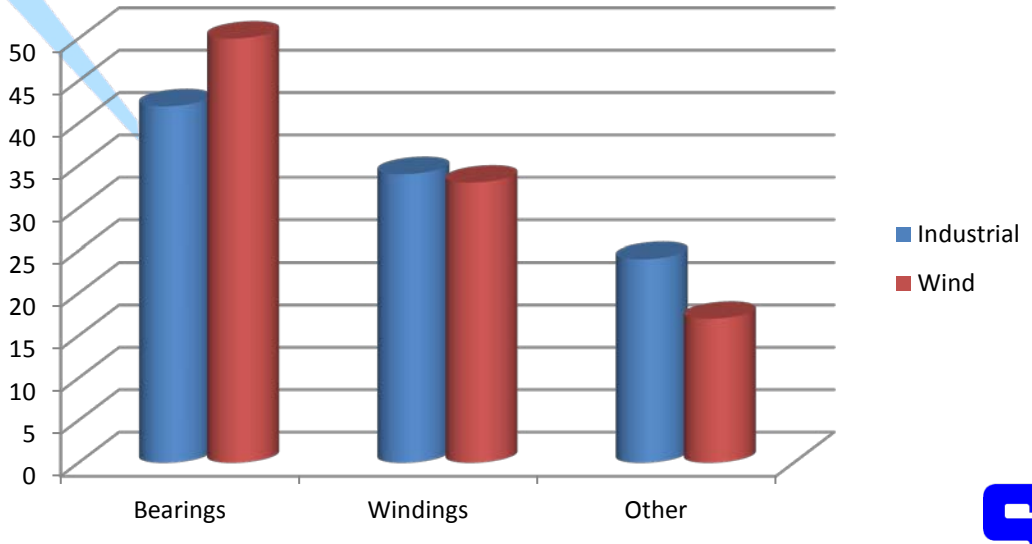
Comparison to General Industry Failures in HV Machines

Based on the new data being compiled by Dr. Peter Tavner and his team at Durham University, Durham, UK, failures due to bearing damage are the leading root cause in both wind and industrial rotating electrical machinery. In fact, with these large studies, there is actually little variation in types of major failures, only in specific machine design areas of vulnerability.



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Updated Failure Information

- Since the initial failure data was collected in mid-year 2010, an additional 300+ generators have been repaired.
- An estimated 50% of these failures are on machines over 5 years old.
- Failure modes have been consistent.
- Proper monitoring of alignment has generally improved but is still an issue at many sites.
- Further analysis will be initiated in 2012.

Conclusions for Owners and Operators

- Bigger and newer is not always more reliable
- Maintenance is THE critical factor affecting machinery life
- To monitor and plan for repair has proven much better than running to failure in many applications
- Choose your suppliers carefully
  - OEMs, replacement components and repairs – all have key influences on reliability and longevity


Thank you for your
time and attention.